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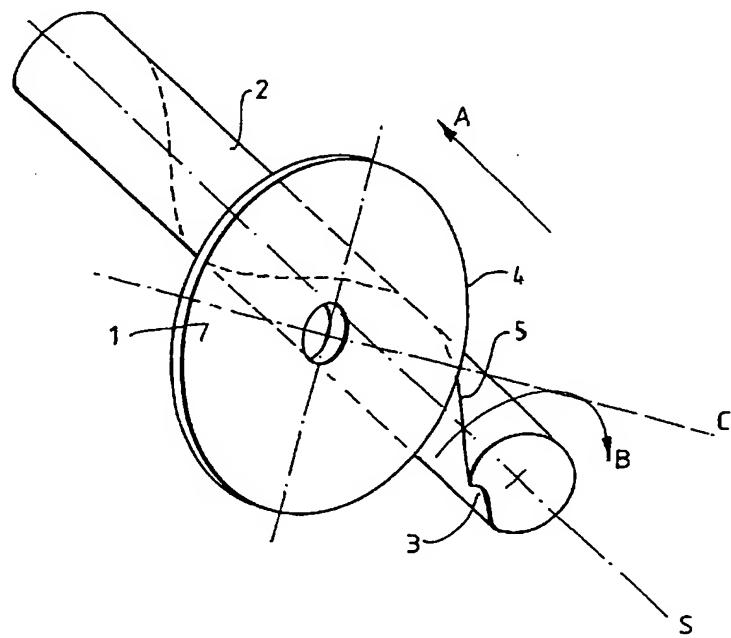
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(54) Title: GRINDING OF CUTTING TOOLS WITH A CONSTANT RAKE ANGLE



(57) Abstract: A method of grinding a surface of a flute (3) on a cutting tool (2) over a range of tool diameters using a grinding machine having a rotatable grinding wheel (1) that is adapted to move relative to the cutting tool. The method includes determining a machine path of the grinding wheel and rotating the grinding wheel and moving it along the machine path to grind a flute surface having a substantially constant rake angle. The invention also relates to a CNC tool grinding machine and a cutting tool.

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## GRINDING OF CUTTING TOOLS WITH A CONSTANT RAKE ANGLE

This invention relates to the grinding of cutting tools. It is particularly concerned with a method of operating a computer numerically controlled (CNC) grinding machine to produce cutting tools with flute surfaces, which maintain a constant rake-angle over a range of diameters, and to such cutting tools produced by the method.

10                   Rotary cutting tools generally have a series of  
helical blades. These blades are generally formed by two  
adjoining faces, a leading face (e.g. a flute surface) and a  
trailing face (e.g. a relief surface). The adjoining faces in  
turn form a crest with a sharp edge of generally smooth  
15                   helical configuration. This edge is usually called the  
cutting edge.

The performance of such cutting tools depends in parts on the geometric configuration of the blade's leading face (e.g. flute surface), and in particular depends on the angle the leading face forms with the surface, which is being machined. This angle is measured in terms of the angle between the tangent of the leading face in radial direction and the surface normal of the machined work-piece surface.

30 One class of cutting tools comprises cutting profiles, which vary in diameter over the length of the tool. Such variations may be smooth and continuous or appear in discrete steps. This class of cutting tools is usually  
35 referred to as Step Tools or Profile Tools. The blades of such Step Tools often comprise a single leading face extending over the full length of the cutting profile. The

rake angle at any point of a cutting edge of any blade of such tools depends on the geometry of the leading face. With existing grinding methods for CNC tool and cutter grinding machines it is not possible to maintain a constant hook or 5 rake angle over the length of the cutting edge of one blade in such Step or Profile Tools.

One other class of cutting tools comprises cutting profiles, which are of generally cylindrical or conical 10 shape. This class of cutting tools is usually referred to as End Mills or Milling Cutters. The economy of cutting tools of this class depends on the ability to re-sharpen the cutting tool. Such tools are usually re-sharpened by re-grinding the outer diameter, reducing the radius of the tool. This 15 reduction in diameter has the effect that a different region of the leading face adjoins the cutting edge, said region determining the rake angle at the cutting edge. For flutes ground with existing prior art, each incremental re-sharpening operation will produce a different rake angle at 20 the cutting edge.

There have previously been proposals to fit inserts into milling cutters with an edge of the insert forming the cutting edge of the cutter. With such inserts it may be 25 possible for the leading face or flute surface to have a constant hook or rake angle over a range of diameters. However, such milling cutters can be expensive to manufacture, possess cutting speed limitations due to inherent material imbalance and hitherto it has not been 30 possible to maintain the constant hook or rake angle when grinding the outer diameter to re-sharpen the milling cutter or cutting tool.

It is therefore desirable to provide a method and 35 CNC tool grinding machine for producing an improved geometry of leading faces (flutes) of cutting tool blades and that said improved geometry being of such nature that it produces

a specified and controlled constant rake angle, independent of a varying cutting profile or diameter of the cutter, which is being ground.

5 According to one aspect of the present invention there is provided a method of grinding a surface of a flute on a cutting tool over a range of tool diameters using a grinding machine having a rotatable grinding wheel that is adapted to move relative to the cutting tool, the method  
10 including:

determining a machine path of the grinding wheel; and

15 rotating the grinding wheel and moving it along the machine path to grind a flute surface having a substantially constant rake angle.

According to another aspect of the invention, there is provided a method of operating a CNC tool grinding machine to grind the flute surface of a cutting tool, the tool  
20 grinding machine having at least one rotatable grinding wheel movable relative to the said method including the programming of the CNC machine with at least one path for the grinding of at least one flute, wherein said method produces a flute geometry, which maintains a substantially constant hook or  
25 rake angle over a range of diameters.

According to another aspect of the invention, there is provided a CNC tool grinding machine, having at least one rotatable grinding wheel movable relative to the cutting tool  
30 for grinding at least one flute surface in the cutting tool, the machine being programmed with at least one path for the at least one grinding wheel which is calculated to grind said flute surface maintaining a substantially constant hook or rake angle over a range of diameters of the flute surface.

35

According to a further aspect of the invention, there is provided a cutting tool having at least one flute

surface produced by the method or by a CNC tool grinding machine in accordance with one of the preceding aspects of the invention, whereby said flute surface has a substantially constant hook or rake angle over a range of diameters of the 5 flute surface.

Preferably, the cutting tool is produced by calculating the wheel geometry of a grinding wheel required to grind a flute surface with a substantially constant hook 10 or rake angle, dressing a grinding wheel in accordance with the calculated wheel geometry, and grinding the cutting tool with the dressed grinding wheel in accordance with a programmed path generated by the CNC tool grinding machine.

15 The wheel geometry is preferably calculated from a three dimensional (3D) model of the flute geometry for a flute surface with the required constant rake-angle in an inverse solving module. The inverse solving module preferably also receives data representing the programmed path for the 20 grinding wheel and calculates machine settings for controlling movement of the grinding wheel along the programmed path to grind the flute surface with the substantially constant hook or rake angle.

25 The CNC tool grinding machine preferably includes input means for entering constant hook or rake cross-section parameters into a programmable control unit of the machine. Flute twist parameters and machine path parameters, such as wheel radius, phase angle and pivot angle, are preferably 30 also input into the programmable control unit (PCU). The constant hook or rake cross-section parameters are preferably used to generate flute cross-section data and the 3D flute geometry is preferably calculated from the flute cross-section data and the flute twist parameters.

35 The programmed path is preferably calculated from the constant hook cross-section parameters, the machine path

parameters and the flute twist parameters.

According to another aspect of the invention there is provided a method of generating a required wheel geometry for dressing a grinding wheel for grinding a flute surface having a substantially constant hook or rake angle over a range of diameters, said method including the steps of, generating a three-dimensional (3D) flute geometry for the required flute surface, generating a programmed path for the grinding wheel to grind the flute surface, and calculating the required wheel geometry for the grinding wheel from the 3D flute geometry and the programmed path.

Preferably, the method also includes the step of generating a two-dimensional (2D) flute cross-section geometry, providing for the constant rake or hook angle.

According to yet another aspect of the invention there is provided a computer program for use with a CNC tool grinding machine, said computer program comprising flute geometry generating means to generate three-dimensional flute geometry data for a flute surface having a substantially constant hook or rake angle over a range of diameters, path generating means for generating a programmed path for a grinding wheel to grind said flute surface with the substantially constant hook or rake angle, and inverse solving means for calculating the required wheel geometry for the grinding wheel to grind said flute surface with the substantially constant hook or rake angle over a range of diameters.

30

In some cases, the required wheel geometry to grind a flute with a constant hook or rake angle over a range of diameters generated by the inverse solving module in the present invention may be difficult to dress on a grinding wheel. In this case, the present invention may include an interactive, iterative method and system for finding an optimum compromise between the wheel geometry's suitability

for dressing and the flute geometry's performance characteristics, while maintaining that portion of the flute geometry which provides for the substantially constant hook or rake angle over a range of diameters.

5

In the interactive, iterative method, the required wheel geometry for grinding a flute with a constant hook or rake angle is generated and both this geometry and the flute geometry may be displayed to the operator. The user can then 10 modify the wheel geometry to a shape that is easier to dress on a grinding wheel. Both the originally generated wheel geometry and the modified wheel may be displayed in the wheel view, allowing the operator to compare his/her modifications to the ideal wheel shape.

15

The system can then automatically generate the changed flute geometry that would be produced by the modified wheel geometry. The changed flute geometry is displayed to the operator superposed to the originally specified flute 20 geometry, again allowing the operator to compare the changed flute shape to the originally desired flute shape.

The operator can then modify the flute geometry again to closer match the desired flute shape. The inverse-25 solving module again automatically generates a new wheel geometry for grinding a flute in accordance with the modified flute geometry. The newly generated wheel geometry is again displayed in the wheel view, superposed on to the previously modified wheel, allowing the operator to compare the newly 30 generated wheel with the previously modified wheel. If necessary, the process can be repeated until a wheel geometry is generated that can produce a flute with a substantially constant hook or rake angle over a range of diameters as well as can conveniently be used to dress a 35 grinding wheel.

According to a still further aspect of the

invention, there is provided a method and system for generating a wheel geometry for a grinding wheel for grinding a flute surface with a substantially constant hook or rake angle over a range of diameters, wherein a wheel geometry for 5 a grinding wheel for grinding a flute surface with a constant hook or rake angle is generated by an inverse solving module using a flute geometry for the required flute surface, wherein parameters for the wheel geometry and flute geometry are able to be modified, and wherein an iterative method is 10 used to generate from a modified flute geometry a new wheel geometry for a grinding wheel for grinding a flute surface with a substantially constant hook or rake angle over a range of diameters.

15 According to still a further aspect of the present invention there is provided a method and system for generating a wheel geometry for a grinding wheel for grinding a real cutting surface of a machine tool, wherein a wheel geometry for a wheel for grinding a desired cutting surface 20 is generated by an inverse solving module using a cutting surface geometry for the desired cutting surface, wherein parameters for the wheel geometry and cutting surface geometry are able to be modified, and wherein an iterative method is used to generate a new wheel geometry for a 25 grinding wheel for grinding the real cutting surface.

A preferred embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

30

Figure 1 is a schematic perspective view of a grinding wheel of a CNC tool and cutter grinding machine operating on a work-piece to grind the flute surface of a blade of a cutting tool;

35

Figure 2 is a schematic perspective view similar to that of Figure 1 with the CNC tool and cutter grinding

machine operating on a stepped work-piece to grind a flute surface, which provides substantially constant hook or rake angle over a range of diameters.

5                   Figure 3 is a schematic block diagram of the control system for a CNC tool and cutter grinding machine in accordance with the invention;

10                  Figure 4 is a cross-section through a flute of a cutting tool having a constant hook or rake angle over a range of diameters;

15                  Figure 5 is an enlarged view of part of the flute cross-section of Figure 4; and

15                  Figure 6 is a block diagram showing procedural steps of the method of the present invention, and

20                  Figure 7 is a flow chart showing an iterative method for generating a wheel geometry for grinding a flute surface with a substantially constant hook or rake angle.

25                  Referring to Figure 1 there is shown a grinding wheel 1 of a CNC tool grinding machine operating on a cylindrical work-piece 2 rotatable about a central longitudinal axis of rotational symmetry S in order to grind a flute surface 3 of a blade with a smooth helical cutting edge. The grinding wheel 1 is substantially disc-shaped and is rotatable about a central axis of rotation C. The grinding 30 wheel has a peripheral grinding edge 4.

35                  The grinding wheel is movable in an axial direction A and a circumferential direction B relative to the workpiece 2 to grind the flute surface 3 of a blade which features a cutting edge 5. In a rotary cutting tool formed from the workpiece 2, the cutting tool usually has a plurality of helical blades, each featuring a flute surface 3 and each

with a cutting edge 5 forming a leading edge of the tool. The angle between the tangent of the leading face (e.g. flute) in a radial direction and the surface normal to the machined work-piece surface is usually called the rake angle or hook angle.

CNC tool grinding machines nowadays have five or more programmable axes, which are used to program a path for the motion of the grinding wheel during its operation on the work-piece. The programmable axes may include physical axes and virtual programmable axes or "soft axes" such as disclosed in our Australian Patent No 665000. In the particular case described with reference to Figure 1 above, the movement of the grinding wheel in the axial direction A and in the circumferential direction B relative to the workpiece may be programmed in terms of the programmable axes of the CNC machine which are not shown in Figure 1.

Conventional CNC grinding methods are generally not capable of grinding flute surfaces with a constant rake or hook angle extending over a range of diameters. This problem is particularly prevalent in the case of Step Tools or Profile Tools in which the diameter of the cutting profile varies over the length of the tool either continuously over a range, such as illustrated in Figure 2, or in discrete steps.

Figure 2 shows a workpiece 2 and grinding wheel 1 similar to Figure 1, and corresponding reference numerals have been applied to corresponding parts. Figure 2 differs from Figure 1 in that the work-piece has an end section 6 of lesser diameter, an opposite end section 7 of greater diameter and an intermediate section 8 of varying diameter. When using conventional methods for grinding flute surfaces 3 on a tool grinding machine, the rake or hook angle of the flute varies in the intermediate region 8 of varying diameter, so that the resultant rake angle in end section 6 differs from that in end section 7.

Figure 3 shows a control system for a CNC tool grinding machine in accordance with the invention. As in a conventional CNC machine, the control system has a 5 programmable control unit (PCU) 10 including parameter input means 12, which may be in the form of a keypad, and a path generator 14 for generating a programmed path for a grinding wheel 1. The CNC machine may also include a trajectory interpolator and position controller module 16 and one or 10 more actuators 18 for moving the grinding wheel 1 relative to a workpiece.

The control system of Figure 3 differs from conventional CNC tool grinding machines in that the parameter 15 input means 12 enables constant hook cross-section parameters to be defined and input to the PCU 10 in addition to flute twist parameters and wheel radius, phase angle and pivot angle parameters.

20 In addition to the path generator 14, the programmable control unit 10 also includes a three-dimensional (3D) flute geometry generator 13 and an inverse solving module 15. This module 15 calculates the required wheel geometry for the given 3D flute geometry with constant 25 hook or rake cross section and the programmed path for the grinding wheel. The wheel geometry data is then passed to a wheel dressing machine 17 which produces the required wheel profile on the grinding wheel 1. The wheel dressing machine 17 may be external to, or integrated with, the CNC tool 30 grinding machine. If the dressing machine is external to the CNC tool grinding machine, the wheel is mounted on the CNC machine after the dressing operation.

One preferred method of programming a CNC grinding 35 machine to grind a flute surface, which maintains a constant rake angle over a range of diameters will now be described with particular reference to Figures 4 to 6. Figures 4 and 5

show the cross-section of a flute having a constant hook or rake angle over a range of diameters. The steps of the preferred procedure are given below.

5           The cross-section geometry of the flute surface is specified (Steps 20 and 22 in Figure 6), typically featuring two distinct sections R and W in Figure 4. The section R closest to the cutting edge is the region of constant hook or rake angle and subject of this invention. The other section W  
10           adjoins the first section and covers the remainder of the flute cross-section. Both these curves can be described as parametric curves.

15            $c_i(t) = (y(t), z(t))$ ,  $i = r, w$ , where  $y(t)$ ,  $z(t)$ , are the co-ordinates defining the points of each curve section. Curve  $c_r(t)$  is defined in such a way, that for any given parameter  $t$ , the tangent  $T$  to the curve point at that parameter forms an angle  $\alpha$  ( ) with the radius to that curve point, which is equal to the specified rake angle. This  
20           is shown in Figure 5 in which the rake angle  $\alpha$  ( ) is the same at all points in section R.

25           The flute twist parameters are specified (Step 24), typically these comprise the axial distance over which the cross section will be rotated one full turn, or the angle between the cutting edge's tangent and that tangent's component in the axial-radial plane of the cutting tool. The first parameter is usually called the "Lead", the latter is usually called the "Helix Angle" of the cutting tool.

30           The machine path parameters are specified (Step 26), these are typically the desired wheel radius, the pivot angle and the phase angle. The pivot angle describes a rotation of the wheel about the wheel plane axis, which is an  
35           axis normal to both the wheel and the cutting tool axes. The phase angle describes the rotation of the flute cross-section about the cutting tool's axis, measured relative to the wheel

plane axis.

5 The flute cross-section of the cutting tool is placed in the x=0 plane (Step 22). Beginning from this position, the cross-section is extruded along the cutting tool axis according to the twist specification (Step 28). This geometric extrusion results in the 3-dimensional surface, which describes the desired surface of the cutting tool flute (Step 30).

10

A transformation function is derived (Step 32) from the constant hook cross-section parameters 22, the flute twist parameters 24 and the machine path parameters 26. The transformation function mathematically describes the machine path 34. For flute grinding, this path is typically a combined motion of the wheel and cutting tool in two axes. The wheel, which is positioned at a distance from the cutting tool axis is simultaneously moved along the cutting tools axis, while the cutting tool is rotating about its own axis.

20

Both the transformation function 34, describing the machining path 34 and the 3-dimensional flute geometry 30 are passed into the inverse solving module 15. This module calculates the required wheel geometry 36 and machine settings 38, according to the transformation function and 3-dimensional flute surface.

30 The wheel geometry is passed to the dressing machine 17, which produces the required wheel profile on a physical grinding wheel 1.

35 The CNC tool grinding machine is programmed with the machine settings output 38 from the inverse solving module 15 and the workpiece is ground 40, to produce a milling cutter with a flute having a constant hook or rake angle over a range of diameters 42.

Referring to Figure 7, there is shown a flow chart of an interactive, iterative process for use in the present invention for generating a wheel geometry for grinding a flute surface with a substantially constant hook or rake angle. The iterative process may be used when the wheel geometry 36 generated for grinding a flute surface with a constant hook or rake angle is not readily usable for dressing a grinding wheel 1 on the wheel dresser 17.

Figure 7 is similar to Figure 6 and corresponding reference numerals have been applied to corresponding parts/steps of the process. Figure 7 differs from Figure 6 in that after the wheel geometry is generated 36 by the inverse solver 15 and displayed, the operator is given the option to determine if the wheel geometry is suitable for dressing 54 and modify the wheel geometry, if it is not suitable for dressing. If the wheel geometry is suitable, it is passed to the wheel dresser 17 for dressing a grinding wheel 1.

If the operator determines that the wheel geometry is not suitable for dressing a grinding wheel, the operator may modify the wheel geometry 58. This may be achieved by the user interactively altering the display of the wheel geometry 56. The modified wheel geometry 58 is then input in to a forward solving module 60. This forward solver calculates the flute cross-section 62, which would be produced by the modified wheel geometry 58. This generated flute cross-section 62 is displayed to the operator.

The operator determines, whether the generated flute cross-section is acceptable 64. If it is acceptable, the generated flute cross-section is fed back 22 into the inverse solving loop, which will generate a wheel geometry 36 identical to that modified by the operator 56. Hence, the iterative loop terminates 54, because the solved wheel geometry 36 is the same as the previously modified wheel geometry 56. The wheel geometry is passed to the wheel

dresser 17, and the physical wheel is dressed 1.

5 If the operator determines that the flute cross-section 62, which would be generated by the modified wheel geometry 58, is not acceptable 64, he can modify the flute shape 66 to create an acceptable flute shape. The modified flute shape is then fed back 22 into the inverse loop. The inverse loop generates a new wheel geometry.

10 If the new wheel geometry is suitable, it may be passed to the wheel dresser 17 for dressing a grinding wheel. If it is again unsuitable for wheel dressing, the iterative process may continue with the operator again modifying the wheel geometry 56, the forward solver 60 generating a new 15 flute cross-section 62, according to the modified wheel geometry 58 and, if necessary, the operator also modifying the generated flute geometry 66.

20 The present invention as described above thus provides an effective method and system for generating a wheel geometry for a grinding wheel to be dressed so that it can be used to grind a flute surface with a substantially constant hook or rake angle over a range of diameters. Further, if the wheel geometry is not suitable for dressing a 25 grinding wheel, the iterative method described above can be used to generate a wheel geometry which is an approximation of the ideal wheel geometry for grinding a flute surface with a constant hook or rake angle.

30 It will be appreciated that various modifications and alterations may be made to the preferred embodiment of the system and process described above with reference to the drawings or that sub-systems or -processes may be extracted, used in isolation or be integrated in systems or processes 35 not described in this patent without departing from the scope and spirit of the invention.

## THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of grinding a surface of a flute on a cutting tool over a range of tool diameters using a grinding machine having a rotatable grinding wheel that is adapted to move relative to the cutting tool, the method including:
  - 5 determining a machine path of the grinding wheel; and
  - 10 rotating the grinding wheel and moving it along the machine path to grind a flute surface having a substantially constant rake angle.
2. The method according to claim 1 comprising:
  - 15 determining the three-dimensional geometry of the flute surface on the cutting tool, the flute surface having a substantially constant rake angle;
  - 20 calculating a required geometry for the grinding wheel according to the calculated machine path and three-dimensional flute geometry; and
  - 25 dressing the wheel to the required wheel geometry.
3. The method according to claim 2 comprisinginputting geometry parameters of the cutting tool to calculate the three-dimensional flute geometry of the flute surface.
4. The method according to claim 3, wherein the geometry parameters include the cross section dimensions of the flute and twist parameters of the flute.
- 30 5. The method according to any one of claims 2 to 4, comprising using machine path parameters and geometry parameters of the cutting tool to calculate the machine path.
- 35 6. The method according to claim 5, wherein the machine path parameters include wheel radius and pivot angle of the grinding wheel, and phase angle of the cutting tool

relative to the grinding wheel.

7. The method according to any one of claims 2 to 6, comprising calculating machine settings of the grinding 5 machine according to the three-dimensional geometry of the flute surface and the calculated machine path.

8. The method according to any one of claims 2 to 7, further comprising modifying the wheel geometry and/or flute 10 shape until the wheel geometry is suitable for dressing a grinding wheel, thereafter dressing the grinding wheel to the modified wheel geometry.

9. A method of operating a computer numerically 15 controlled (CNC) grinding machine to grind a surface of a flute of a cutting tool, the grinding machine having at least one rotatable grinding wheel moveable relative to the cutting tool, said method including programming the CNC machine with a path for the grinding of the flute wherein said method 20 produces a flute geometry, which maintains a substantially constant rake angle over a range of cutting tool diameters.

10. The method according to claim 9 wherein the method includes calculating a wheel geometry of the grinding wheel 25 required to grind a flute surface with a substantially constant rake angle, dressing a grinding wheel in accordance with the calculated wheel geometry, and grinding the cutting tool with a dressed grinding wheel in accordance with a programmed path generated by the CNC grinding machine.

30 11. The method according to claim 10, wherein the grinding wheel geometry is calculated from a three-dimensional model of the flute geometry for a flute surface with the required constant rake angle in an inverse solving 35 module.

12. The method according to claim 11 comprising feeding

the inverse solving module with data representing the programmed path for the grinding wheel and calculating machine settings for controlling movement of the grinding wheel along the program path to grind the flute surface with 5 a substantially constant rake angle.

13. The method according to any one of claims 9 to 12 including entering constant rake cross-section parameters into the input of a programmable control unit of the CNC 10 machine.

14. The method according to claim 13 comprising entering flute twist parameters and machine path parameters including wheel radius, phase angle and pivot angle into the 15 programmable control unit.

15. The method according to claim 14 comprising using the constant rake cross-section parameters to generate flute cross-section data and calculating the three-dimensional 20 flute geometry from the flute cross-section data and the flute twist parameters.

16. The method according to claim 15, comprising calculating the program path from the constant flute cross- 25 section parameters, the machine path parameters and the flute twist parameters.

17. A cutting tool produced by the method of any one of claims 1 to 16.

30

18. A cutting tool comprising a tool body having varying diameters, the tool body defining a helical flute surface wherein the flute surface is produced by a grinding process on a CNC grinding machine to provide a substantially 35 constant rake angle over all diameters of the cutting tool.

19. A computer numerically controlled (CNC) grinding

machine for grinding cutting tools, the machine including a rotatable grinding wheel that is adapted to move relative to the cutting tool to grind a flute surface in the tool, the machine being programmed with at least one path for the  
5 grinding wheel which is calculated to grind said flute surface maintaining a substantially constant rake angle over a range of diameters of the flute surface.

20. The CNC grinding machine according to claim 19  
10 including input means for entering flute cross-section parameters into a programmable control unit of the machine.

21. The CNC grinding machine according to claim 20, wherein the programmable control unit has the capabilities to  
15 receive flute twist and machine path parameters including wheel radius, phase angle of the cutting tool relative to the grinding wheel, and pivot angle of the grinding wheel.

22. The CNC grinding machine according to either claims  
20 20 or 21, wherein constant rake parameters are used to generate flute cross-section data and the 3-D flute geometry is calculated from the flute cross-section data and the flute twist parameters.

25 23. The CNC grinding machine according to claim 22 wherein the programmed path is calculated from the constant rake parameters, the flute cross-section parameters, the machine path parameters and the flute twist parameters.

30 24. The CNC grinding machine according to any one of claims 19 to 23, wherein the machine includes dressing means to dress the grinding wheel to a required wheel profile.

25. A method of generating a required wheel geometry  
35 for dressing a grinding wheel for grinding a flute surface having a substantially constant rake angle over a range of diameters, said method including the steps of,

generating a three-dimensional (3-D) flute geometry for the required flute surface,

generating a programmed path for the grinding wheel to grind the flute surface, and

5 calculating the required wheel geometry for the grinding wheel from the 3-D flute geometry and the programmed path.

10 26. The method according to claim 25 including the step of generating a two-dimensional (2-D) flute cross-section geometry, providing for the constant rake angle.

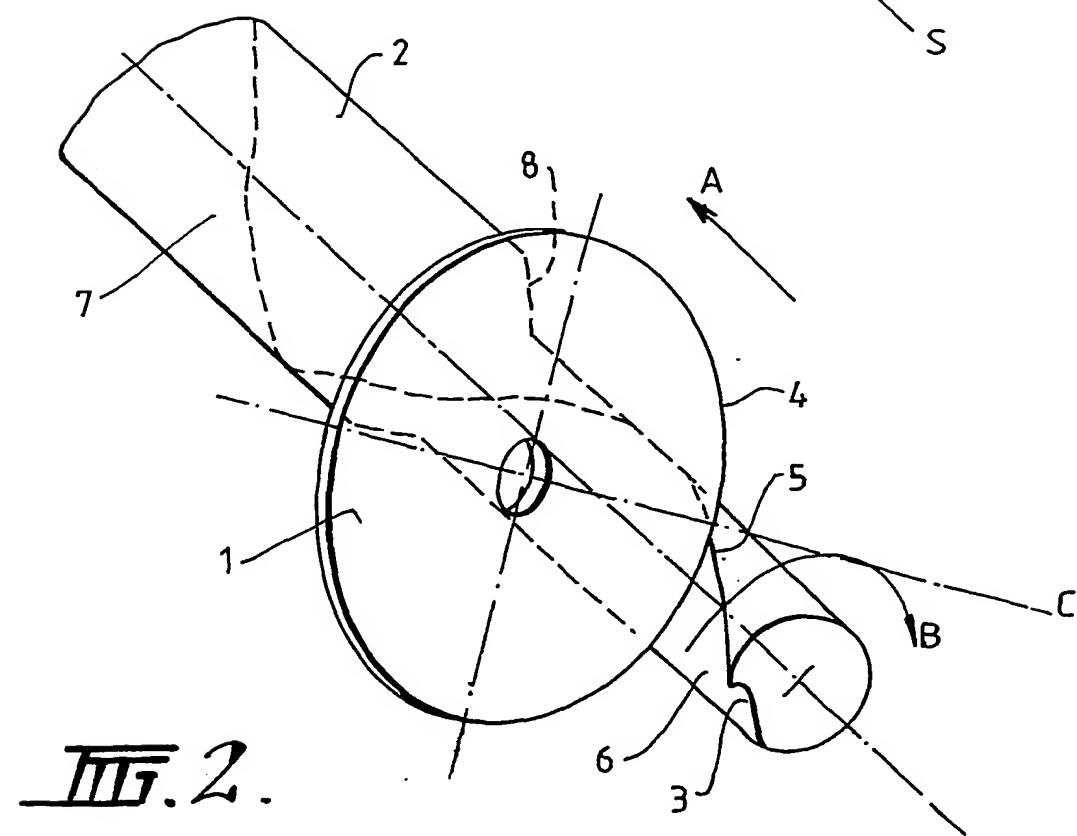
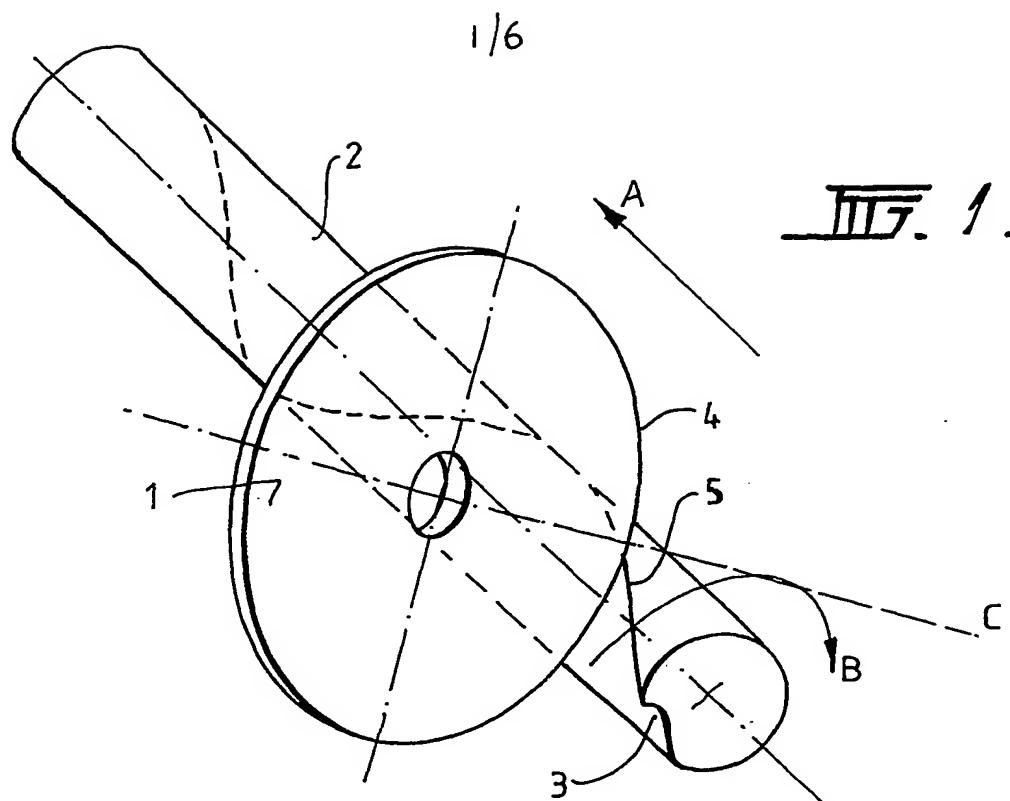
15 27. A computer program for use with a computer numerically controlled (CNC) grinding machine for grinding cutting tools, the computer program comprising flute geometry generating means to generate three-dimensional flute geometry data for a flute surface having a substantially constant rake angle over a range of tool diameters, path generating means for generating a program path for a grinding wheel to grind 20 said flute surface with the substantially constant rake angle, and inverse solving means for calculating the required wheel geometry for the grinding wheel to grind said flute surface with the substantially constant rake angle over a range of tool diameters.

25 28. A method and system for generating a wheel geometry for a grinding wheel for grinding a real cutting surface of a machine tool, wherein a wheel geometry for a wheel for grinding a desired cutting surface is generated by an inverse 30 solving module using a cutting surface geometry for the desired cutting surface, wherein parameters for the wheel geometry and cutting surface geometry are able to be modified, and wherein an iterative method is used to generate a new wheel geometry for a grinding wheel for grinding the 35 real cutting surface.

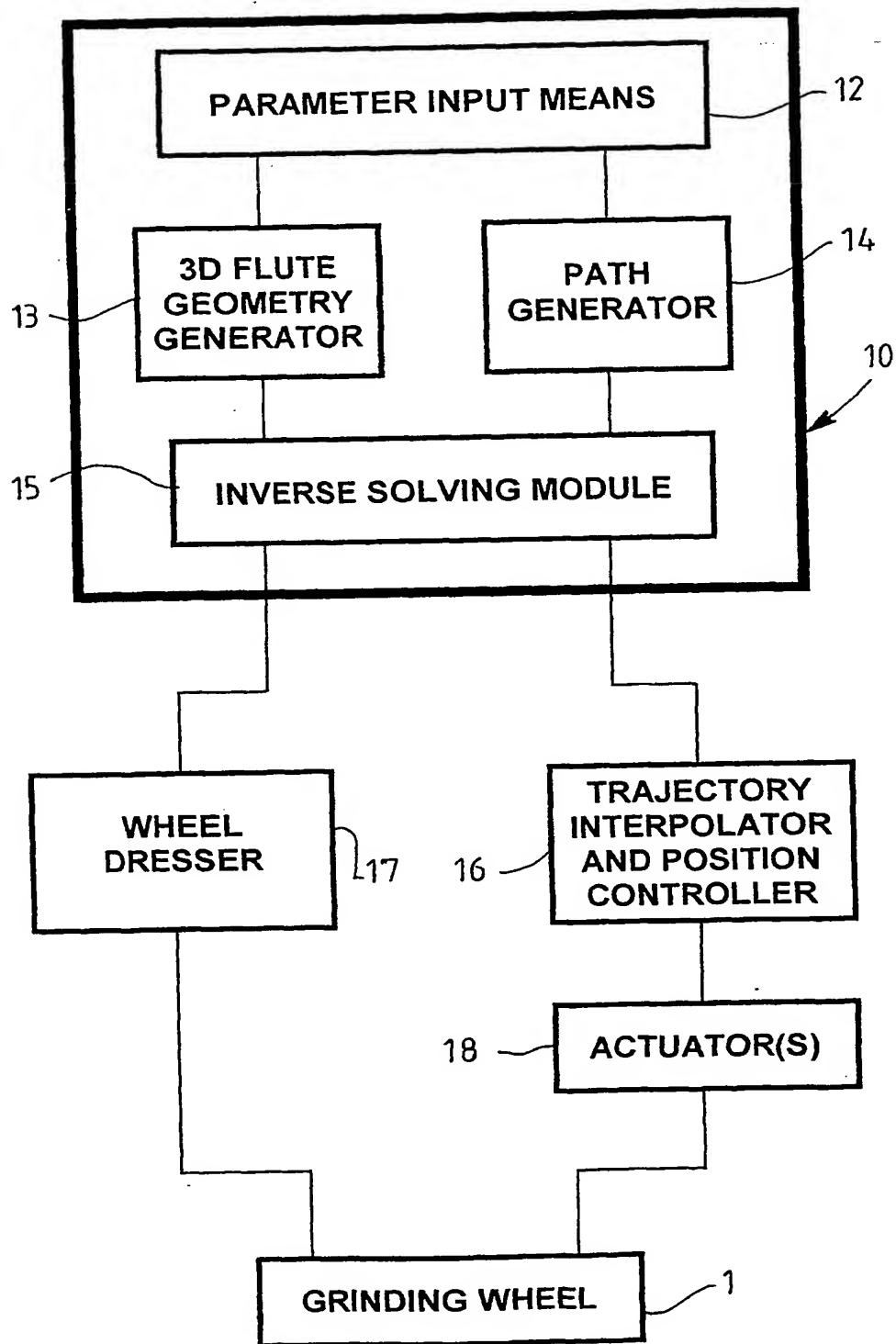
29. A method and system for generating a wheel

geometry for a grinding wheel for grinding a real flute surface with a substantially constant rake angle over a range of tool diameters, wherein a wheel geometry for a wheel for grinding a desired flute surface with a constant rake angle 5 is generated by an inverse solving module using a flute geometry for the desired flute surface, wherein parameters for the wheel geometry and flute geometry are able to be modified, and wherein an iterative method is used to generate a new wheel geometry for a grinding wheel for grinding the 10 real flute surface with a substantially constant rake angle over a range of tool diameters.

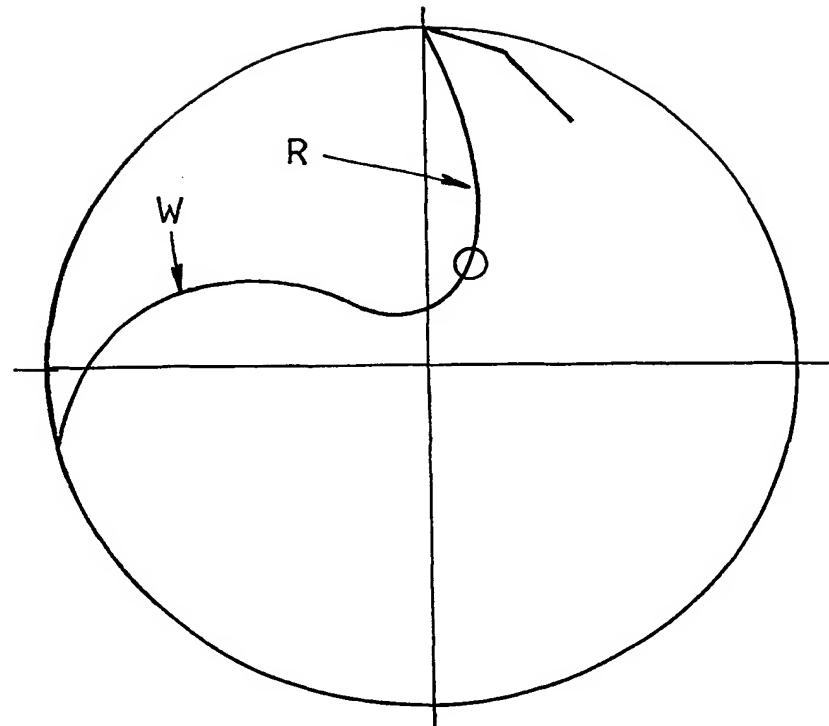
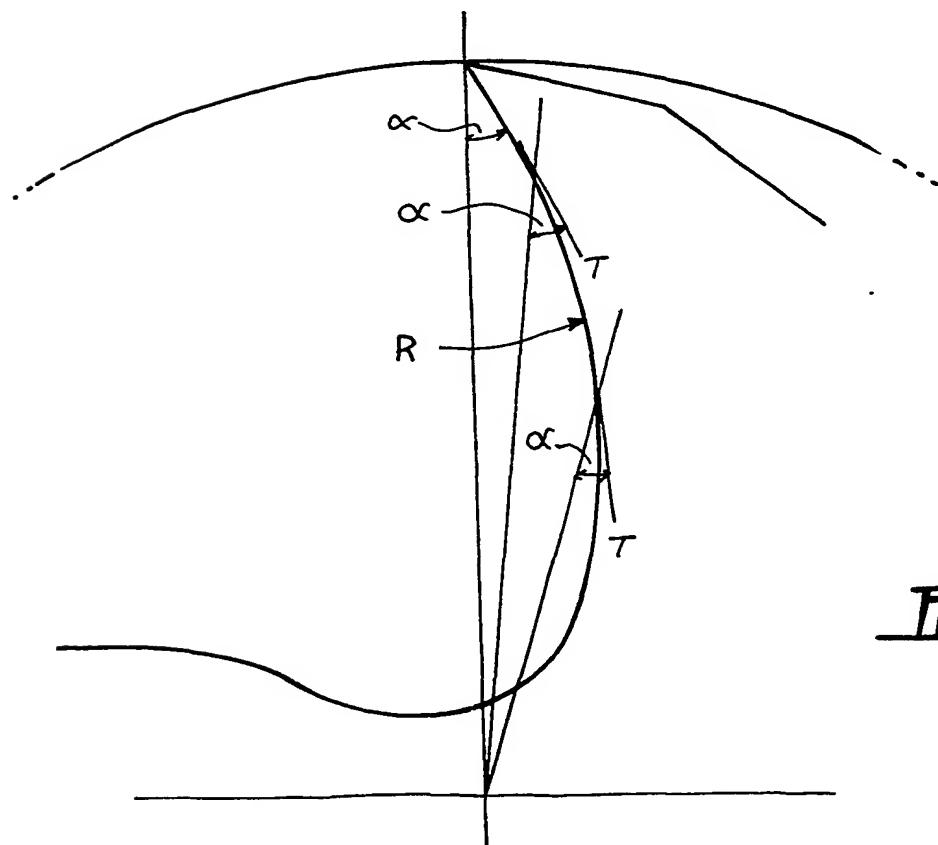
30. The method and system of claim 29 wherein the iterative method comprises modifying the flute geometry if 15 the wheel geometry is unacceptable and/or modifying the wheel geometry if the flute geometry is unacceptable until both geometries are acceptable.



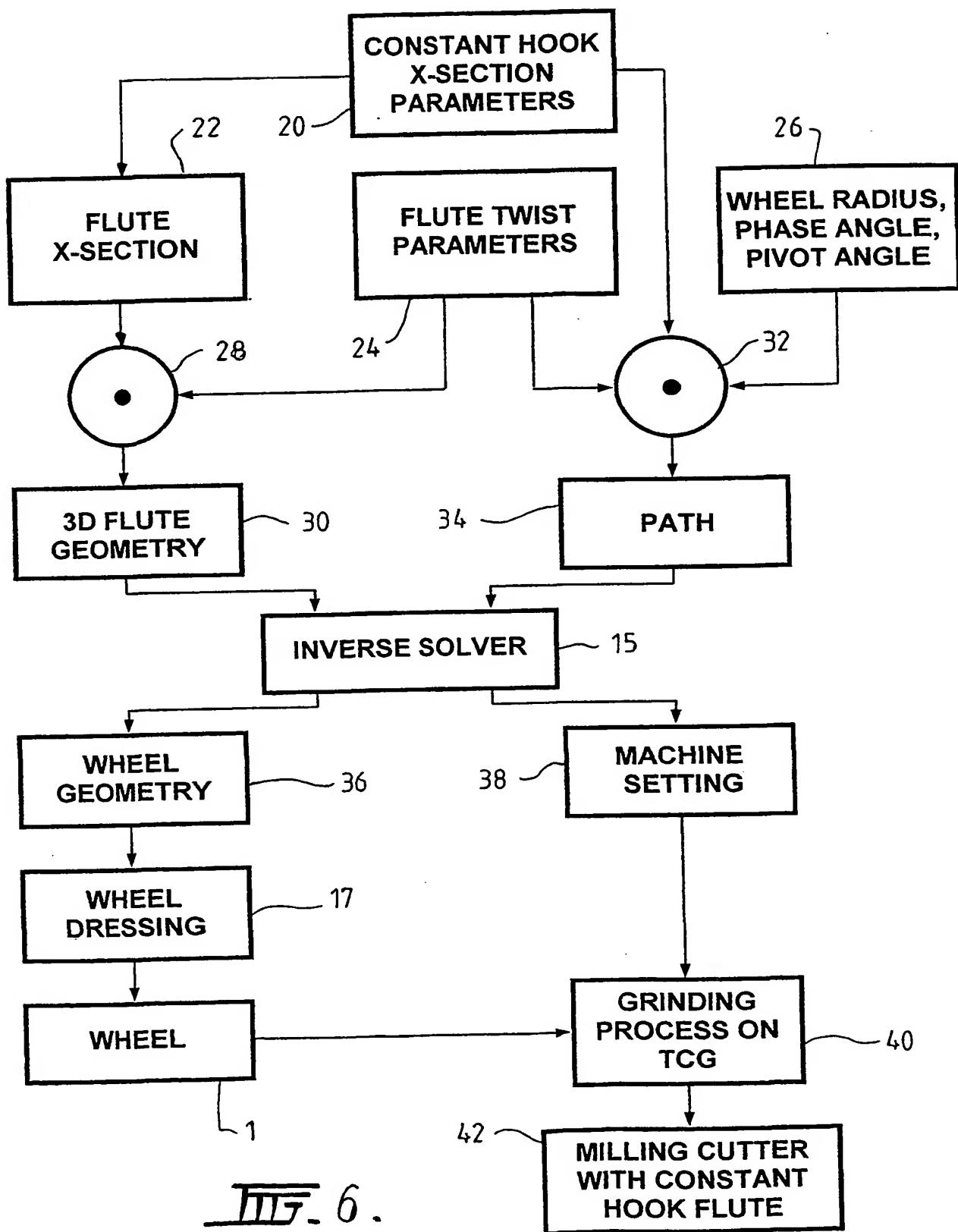
2/6

FIG. 3.

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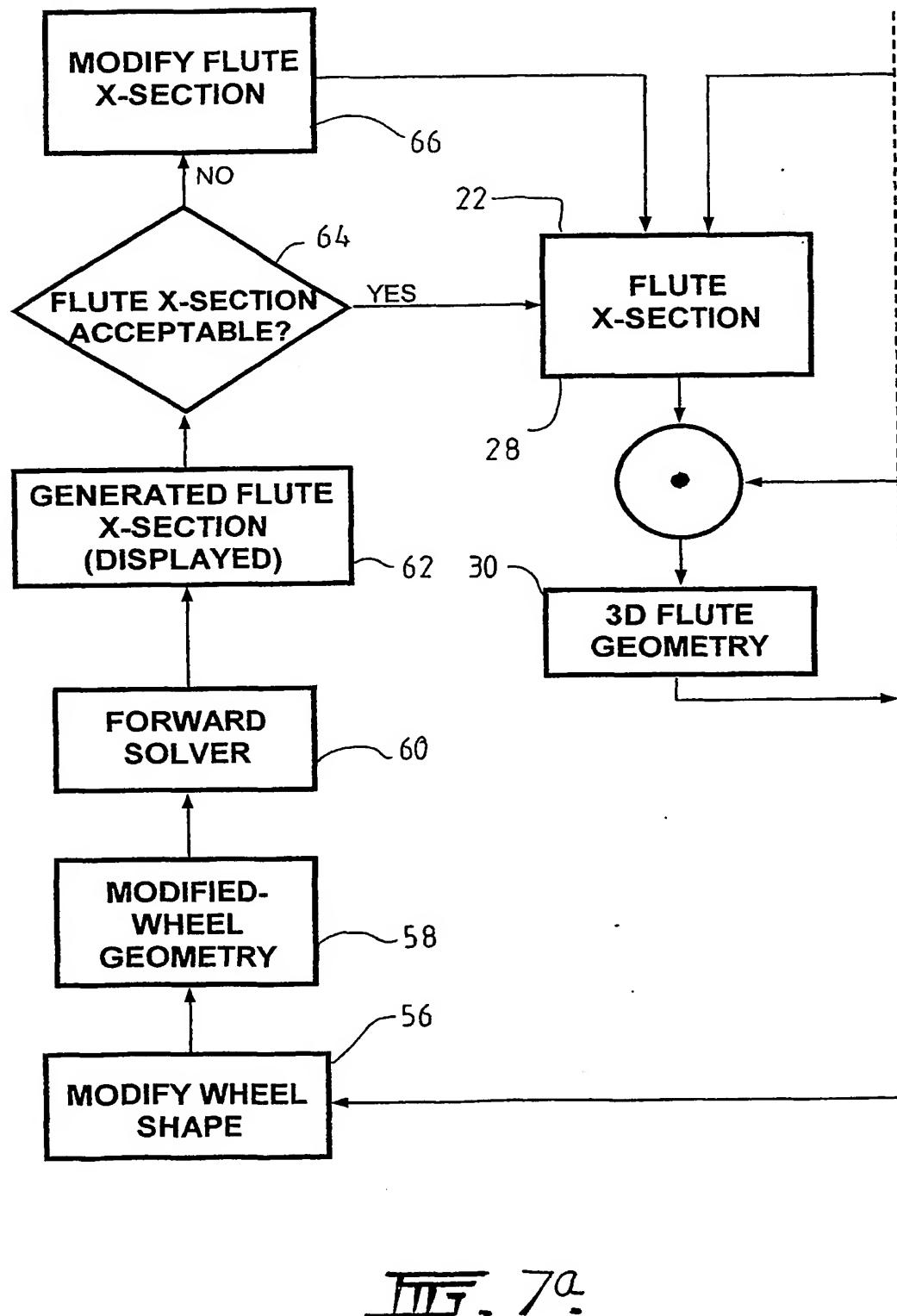
III. 4.III. 5.

4|6

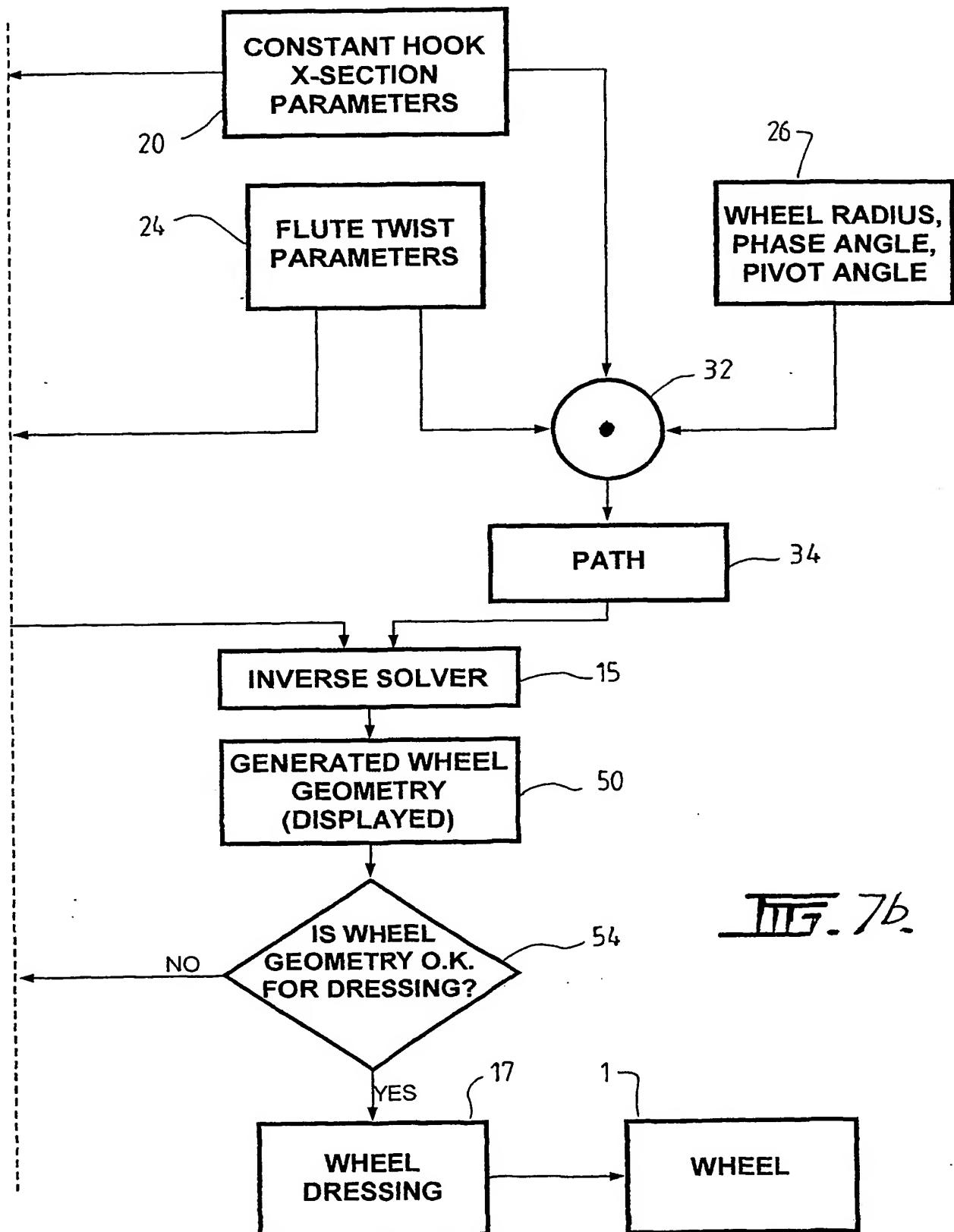


III. 6.

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III. 7a

6/6



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU01/01116

## A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: B24B 17/00, 19/04

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B24B 17/00, 19/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 99/43469 A (ORMCO CORPORATION) 2 September 1999. Whole document	1-27
A	DE 2629130 A (JUNKER ERWIN) 12 January 1978. Whole document	1-27
A	US 4890419 A (ZANG) 2 January 1990. Whole document	1-27

Further documents are listed in the continuation of Box C  See patent family annex

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search  
14 November 2001Date of mailing of the international search report  
19 NOV 2001Name and mailing address of the ISA/AU  
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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/AU01/01116

## Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos :  
because they relate to subject matter not required to be searched by this Authority, namely:
  
  
  
  
  
2.  Claims Nos :  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
  
  
  
  
3.  Claims Nos :  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

## Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claims 1-27 are directed to a cutting tool and method of grinding a surface of a flute on the cutting tool.
2. Claims 28-30 are directed to a method and systems for generating wheel geometry for a grinding wheel.
  
1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
  
  
  
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:1-27

## Remark on Protest

The additional search fees were accompanied by the applicant's protest.  
 No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU01/01116

**Supplemental Box**

(To be used when the space in any of Boxes I to VIII is not sufficient)

**Continuation of Box No: II**

1. Claims 1-27 are directed to a cutting tool and method of grinding a surface of a flute on the cutting tool including having a machine path of the grinding wheel to grind a flute surface having substantially constant rake angle.
2. Claims 28-30 are directed to a method and systems for generating wheel geometry for a grinding wheel including an iterative method is used to generate new wheel geometry for grinding the real cutting surface.

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
**PCT/AU01/01116**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report			Patent Family Member		
WO	43469 A	NONE			
DE	2629130 A	NONE			
US	4890419 A	DE 3706948 A	EP 281025 A	JP 1228763 A	